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Abstract

Price-based interventions (such as Time of Use tariffs) are designed to shift the timing of certain everyday activities to mitigate peak electricity demand. On the one hand, it is argued that timing activities outside the peak hours would decrease the demand, easing the stress on the grid. On the other hand, recent literature suggests that householders are more likely to ignore timing of activities – due to convenience or due to activities considered 'non-negotiable' during peak hours. One way to address this conundrum is to investigate how family-related activities during the peak times hang together and the extent to which they are performed together at a specific time of the day. The starting point of this research is that working hours and school times shape the dynamics of peak demand, leaving less time for families to do more during these time periods and also making it difficult to shift activities to other times of the day. We aim to explore the timing and sequences of activities, comparing how they vary at different temporal scales (e.g. workdays vis-à-vis school holidays). In conclusion, we argue that any effective shifting of family-related activities will need to look beyond the meter (such as de-synchronized effects of school holidays), potentially collecting information regarding both energy and non-energy data in order to understand the connection, coordination and organization between activities which constitute electricity demand.

Introduction and aim of this paper

In 2017, the domestic energy use accounted for 28 % of total energy consumption in the UK (ECUK 2018). Of this, 19 million are registered as UK families and there are 7.9 million families with at least one dependent children (OFS 2017). Households with children consume more energy than those without and this consumption increases as children grow older (Brounen et al. 2012). When looking at actual numbers of children engaging in any sort of media and communications, the largest numbers are found between 18:30–20:15 (Ofcom 2014). During this time children watch TV, play computer games and browse the internet.

An increasing number of Government initiatives are aimed at reducing electricity consumption at peak time by introducing an electricity tariff based on the time of the day. Time-of-use tariffs have been found to promote a drop in peak demand of 3–6 % (Faruqui et al. 2010). The effectiveness of the price-based interventions (e.g. time-use tariffs) to shift the timing of certain activities is still a source of debate in the UK. According to Citizens Advice UK (2017), time-of-use tariffs could promote a drop in peak demand of between 5 %–10 %, but in a similar way they could increase bills for those consumers who are unable to change their consumption patterns. Therefore, if price-based interventions to decrease peak electricity demand are to be effectively implemented, it is important to know which activities can shift to other times of the day (Strengers 2018). Rather than trying to 'discourage' consumption in this paper we suggest exploring supportive non-energy policies (workdays vis-à-vis school holidays) that could steer demand reduction.

The aim of this paper is twofold: (1) presenting findings on the timing of family related activities (e.g. workdays vis-à-vis

school holidays) and (2) suggest a method that can be used to explore the way non-energy polices influence the trajectories of energy-intensive social practices as well patterns of energy demand.

The paper is organised as follows. First, we expand on the definition of energy sufficiency used in this paper as well the way sufficiency is connected to 'invisible energy-policy'. Following a short presentation of the methodology, we present results on the timing of family related activities. The paper ends with a short conclusion.

ENERGY SUFFICIENCY AND THE TIMING OF ENERGY-RELATED ACTIVITIES

A first essential step in studying energy sufficiency – i.e. the level of energy service consumption that supports human and ecological wellbeing (Darby et al. 2018) – consists of understanding the timing associated with energy-related activities. This calls for an investigation on the use of time (Southerton 2003) and specifically on the timing of energy-related activities (Palm et al. 2018). The timing of different activities can be explored with ethnographic studies (Higginson et al. 2015, Nicholls et al. 2018) as well through national time use surveys (Torriti 2017). Those who used the national time use surveys to explore the people activities during peak time suggest that activities vary significantly based on gender and presence of a child. For example house work and paid work as well media use differ between men and women (Torriti 2015).

From a policy perspective, the make-up of energy demand is influenced by areas of policy other than energy. Thus, the energy demand which is the outcome of what householders do at home and at work is shaped by energy policies, but mostly by 'non-energy policies' (Royston et al. 2018). From this point of view, the potential for developing energy sufficiency policy to realise demand reduction depends on developing supportive non-energy policy that are consistent with people's activities and yet 'steer' demand (Royston et al. 2018).

In this paper we suggest a method that can be used to analyse the way in which non-energy polices influence the trajectories of energy-intensive social practices as well patterns of energy demand (Royston et al. 2018).

SOCIAL PRACTICES AS A LENS FOR UNDERSTANDING AND INTERVENING IN THE DYNAMICS OF FAMILY-RELATED PRACTICES

Practice theories have been applied in the energy demand domain to understand intra-day variations in residential electricity demand in relation to everyday life (Shove et al. 2014). In this paper we use a social practice perspective to diagram the way work-schedules influence the connections between family-related practices. The paper investigates what kind of practices are performed by families on a daily basis and how the connection between practices change based on different type of work schedules.

Central to this paper is the proposition that practices in everyday life are linked together to form a nexus of interconnected practices that organise the time-space of social life (Schatzki 1996). For example, doing the laundry consists of several individual practices such as selecting the laundry, loading the washing machine, drying the clothes, ironing and storing laundered clothes and others. While these are separate practices, they are usually bundled together when performing the laundry practices. The way practices connect to each other can be characterised as either in harmony or conflict (Schatzki 1996). More generally, while some practices might be incompatible, others connect together to create bundles meaning that practices depend on each other (Shove et al. 2012).

Throughout the paper, we draw on the connection between practices to explore the way family related practices connect to each other. In particular we are interested in the duration (how long particular family related activities last for), sequence (the order in which family related practices are done) and temporal location (where in the day or week activities are located), as these are all relevant for the analysis that follows. Our ultimate aim is to use connections and relationships between practices in order to suggest to policy makers a method to explore the way non-energy polices influence the trajectories of energy-intensive social practices as well patterns of energy demand (Royston et al. 2018).We do so by offering visualisation of practices interconnections and interpretation of interventions. The idea of diagramming the connection between and within practices was set out in other work by Kuijer (2014) and Higginson et al. (2015). The bubble model (Kuijer 2014) is specifically developed to support practice designers in understanding the difference between practice-as-entity and practice-as-performance as well to conceptualise change in practice perspective[1]. Kuijer extends the Shovean images, skills and stuff model (Shove et al. 2005) by diagramming the elements of practices as bubbles and the links as multitudes of links. If for Shove the 'stuff' of showering is the shower for Kuijer the "stuff" is defined by element categories (or bubbles) such as the shower curtain, soap, heat, electricity or water.

Using the Shovean (2012) practice model Spurling et al. (2013) suggest three models of policy interventions that take social practices as sites of intervention: recrafting practices, substituting practices and changing how practices interlock. In this paper, we use the 'interlocking practices' framing to explore the dynamics of consumption between non-policy measures (e.g. work schedules and school times) and daily practices performed during peak electricity time within households with children. The interlocking practice model focuses on bundles of practices: 'how changing a practice – such as food shopping – has effects on and implications for other practices – such as driving'. Most importantly, practices interlock through sequence and synchronization.

Thus an energy-sufficiency based policy design can include change in temporal organization of working times to encourage people to eat at collectively defined times (Southerton et al. 2011) or change the 'sequential ordering of food provisioning (such as shopping, storing, cooking and eating food) in relation to everyday rhythms' (Southerton et al. 2011) to encourage local sourcing food and to reduce food waste. In the following, we will present our methodological approach.

Research framework and method

The analysis is based on the 2014–2015 nationally representative UK Time Use Survey data. The Time Use Survey consist of two parts: (i) activity diaries that provide information about

1. Practice-as-entity is used to define practice in its stable state by its interrelated elements (Schatzki 1996). Practice-as-performance refers to the doing or performing of a practice (Schatzki 1996).

Table 1. Household distribution by gender and work status (UKTUS 2014–2015).

Gender from household grid	Economic activity status									
	Self empl	In paid e	Unemploye	Retired	On matern	Looking a	Full-time	Long-term	Doing som	Total
Male	51	158	5	94	0	3	2	6	0	319
Female	38	155	2	93	6	33	5	3	1	336
Total	89	313	7	187	6	36	7	9	1	655

Table 2. Household distribution by number of children and work status (UKTUS 2014–2015).

Number of children in household	Economic activity status									
	Self empl	In paid e	Unemploye	Retired	On matern	Looking a	Full-time	Long-term	Doing som	Total
1	43	134	4	86	1	14	3	5	0	290
2	41	121	2	66	3	22	1	4	0	260
3	4	36	1	27	1	0	3	0	1	73
4	1	16	0	8	1	0	0	0	0	26
5	0	6	0	0	0	0	0	0	0	6
Total	89	313	7	187	6	36	7	9	1	655

what individuals are doing and when during 24-hour periods; and (ii) a household survey that includes sociodemographic information about respondents, including the relation between the householders, family structure, household income, age of the respondents, occupations, and employment status amongst others. In the diaries, activities of 4,741 households (and 11,421 individuals) are recorded in 10 minutes intervals during a week and weekend day. A day begins at 04:00 and ends the following day with the last recording at 03:50–04:00. The diaries provide information about: (a) primary activities; (b) secondary activities; (c) location where the activity took place; (d) who respondents were with; (e) level of enjoyment and (f) whether a device (computer/smartphone/tablet) was used. Other information recorded in the diary consists of date of completion or type of day (e.g. work day, or other type of day). For the analysis of the UK Time Diary Study five weights are provided: household weight (hh_wt), individual weight (ind_wt), diary weight at day level (dia_wt_a), diary weight at individual level (dia_wt_b) and 7-day work schedule weight (wks_wt). In this paper diary weight at individual level (dia_wt_b) as well 7-day work schedule weight (wks_wt) were used.

In total there are over 270 activity codes that the respondents could choose from to describe their activities. To reduce the computational requirements and to focus on electricity consumption associated with activities, the activity codes were grouped by similarity (e.g. "watching sports on TV" or "watching films on DVD" grouped as "Watching TV") and whether an activity is likely to be directly linked with electricity consumption. Families with children were selected based on socio-demographic information collected from individual and household survey. From this dataset only people who reported having a child as well being married or cohabiting were selected for this study, resulting in a sample of 655 households. Table 1 and Table 2 show the gender, number of children and work status of families. There is only a marginal difference in work status between men and women.

Merging the household surveys with the individual surveys allowed the identification of different socio-demographics such as (a) Number of children in the household (variable DM016 from UKTUS household survey); (b) Employment status of the residents of 16 year-olds and above: self-employed, employed, retired or unemployed (variable WorkSta from UKTUS individual survey); (c) Number of residents in full-time education (value 7 from variable WorkSta from UKTUS individual survey); (d) Employment status of 16 year-olds and above: self-employed, employed, retired or unemployed (variable WorkSta from UKTUS individual survey); and (f) Employment status of 16 year-olds and above: self-employed, employed, retired or unemployed (variable WorkSta from UKTUS individual survey).

In addition to distinguishing between different work schedules and between what families do when children are in school vis-à-vis on holidays, we analyse the connection between the activities using the network degree metric. Mckenna et al. (2016) argue that this metric is useful in defining anchors in people lives, i.e. activities that are more connected to other activities.

Work schedules and school

WORK SCHEDULES

In addition to the time-use diaries, the National Time Use Survey provides a separate dataset with information about paid working time over a continuous period of seven days. The data

set contains information of weekly work schedules recorded by 3,523 respondents in 15 minutes. The timing of the work schedules varies based on when, where and how work is carried out. The work schedule diaries allowed us to identify the timing of different types of work arrangements and shift patterns. The most frequent work schedules reported by families with children consist of Monday to Friday from 09:00 to 12:45 with a break between 12:45 and 14:00 followed by a few hours of work from 14:00 to 16:45. Weekday activities for each individuals were merged with the work schedules diaries with the aim to identify the timing and coordination of practices based on different work schedules.

Figure 1 reveals the timing of the most frequent activities in households with children and the way they are influenced by householders' working status. The plot reveals a clear rhythm of the day with morning routines, family peak times as well evening downtime. We may say that practices are synchronised around work schedules that orient family life. Furthermore, according to Figure 1 the 'family peak' time corresponds to the peak periods of the TOU electricity tariff. Examples of practices performed during peak electricity period include food management, TV and radio entertainment or socializing. The timing of these activities start before and continue during the 'peak hours' that makes difficult to shift to later hours. A way out of this blind could be an energy sufficiency based policy that could support the rhythms and routines of family life. One example of supportive non-policy measure for shifting family peak time is suggested by Nicholls et al. (2015) in hot weather climates. This consists of an incentive-based measure that would reward households to leave the house on a hot peak day by supporting activities such as free movie tickets (Nicholls et al. 2015).

In this paper we suggest a way to explore the connections between practices and the way they hang together.

CHILDREN IN SCHOOL AND ON HOLIDAYS

We derived the UK school holidays from a UK Government website[2] and we used the diary dates that were filled in during the school holidays. We also analysed the timing and sequencing of activities before and during school holidays between 25 June and 1 September 2014.

Figure 2 highlights the difference in the timing and duration of activities during weekdays and school holidays. In general, holidays are specific days of the year where people change their behaviours. For example on Figure 2 the change in behaviour can be spotted in timing of transport pattern as well in the timing of school or university related activities.

An initial approach in research to exploring the effect of school holidays on energy demand was from a mobility perspective. With the increasing number of right term holidays the German Secretary of Education suggested spreading school holidays across the calendar in order to reduce travel costs as well carbon emissions associated with flights and hotels. An agreement was signed between the German regional governments to reshape the summer holiday in such a way to 'as to avoid all of the regions' leisure-seekers leaving for and returning from their holiday at the same time, with the corresponding detrimental effects on traffic and demand for accommodation in tourist areas.' In line with this agreement Germany was divided into population block and each region could autonomously define its summer school holidays.

Royston et al. (2017) frame this issue as: "… in the field of transport studies, it is widely recognised that demand for mobility (and hence for fuel) is an outcome of non-transport policies, such as those affecting urban planning, business, education and health". Similarly, our analysis looks into the way energy-related activities at home change between terms and school holidays.

Exploring family-related practices by diagramming the connections between social practices

Figure 3 provides a comparison overview of the most frequent weekday sequences of activities recorded in survey during peak times in families with children and during periods of school holidays. The network graph was created by merging individuals' activities with their work schedules. The colour of the nodes define the degree of connectedness of a node within a network. The nodes are scaled according to the centrality of the practice network. During the term-time, activities related to food preparation are considered to be the most central and during the holiday periods activities related to travel by purpose are considered to be central. The edges or the connections are coloured according to the source of activity. The activity nodes are sized based on their incoming connection (in and out degrees) and this way are an indication of how much an activity sequence 'hubs' they are. We define hub as an activity with many in and out degree connections. The graphs shows that activities related to travel and employment are closely connected.

Using the network degree metric we find that travel activity is associated with the highest number of connections, followed by food preparation, eating and mass media activities. These activities could provide a starting point in interlocking practices as they are central, difficult to shift to spatial location (Southerton 2006, Hargreaves 2011). Thus even though the network those not explain why eating is so central to the network it allows to explore how intervening in specific activities could impact other activities.

According to Torriti et al. (2015) preparing food, washing up and/or travelling are among the activities that have the highest estimated greenhouse gas intensities; therefore activities that most central from a network perspective are the most important to decarbonise.

Looking at the degree distribution of the network (Figure 4) we can identify activities that are 'anchors' in people everyday life. In this case food management has the highest number of in degree followed by activities related to employment. Therefore supportive a non-policy measure to food management and working hours may steer demand reduction during peak hours. An examples of non-policy measures in this case could be related to intervention that promote trends like eating out in a local community, especially during the daytime or while work.

2. School term and holiday dates: https://www.gov.uk/school-term-holiday-dates.

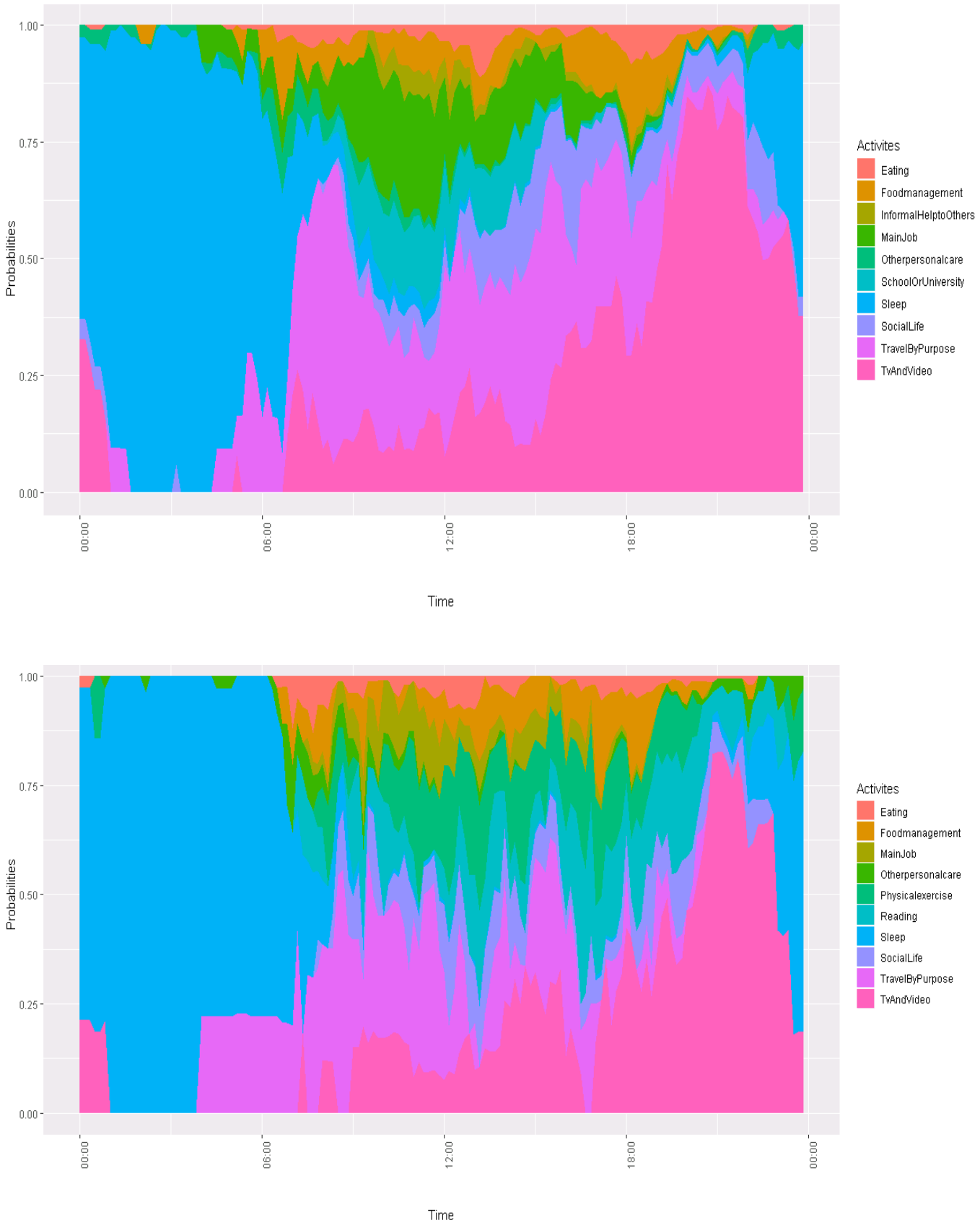

Figure 1. Comparison of the timing of 10 most frequent activities between households who reported working full time (top) and part-time (bottom).

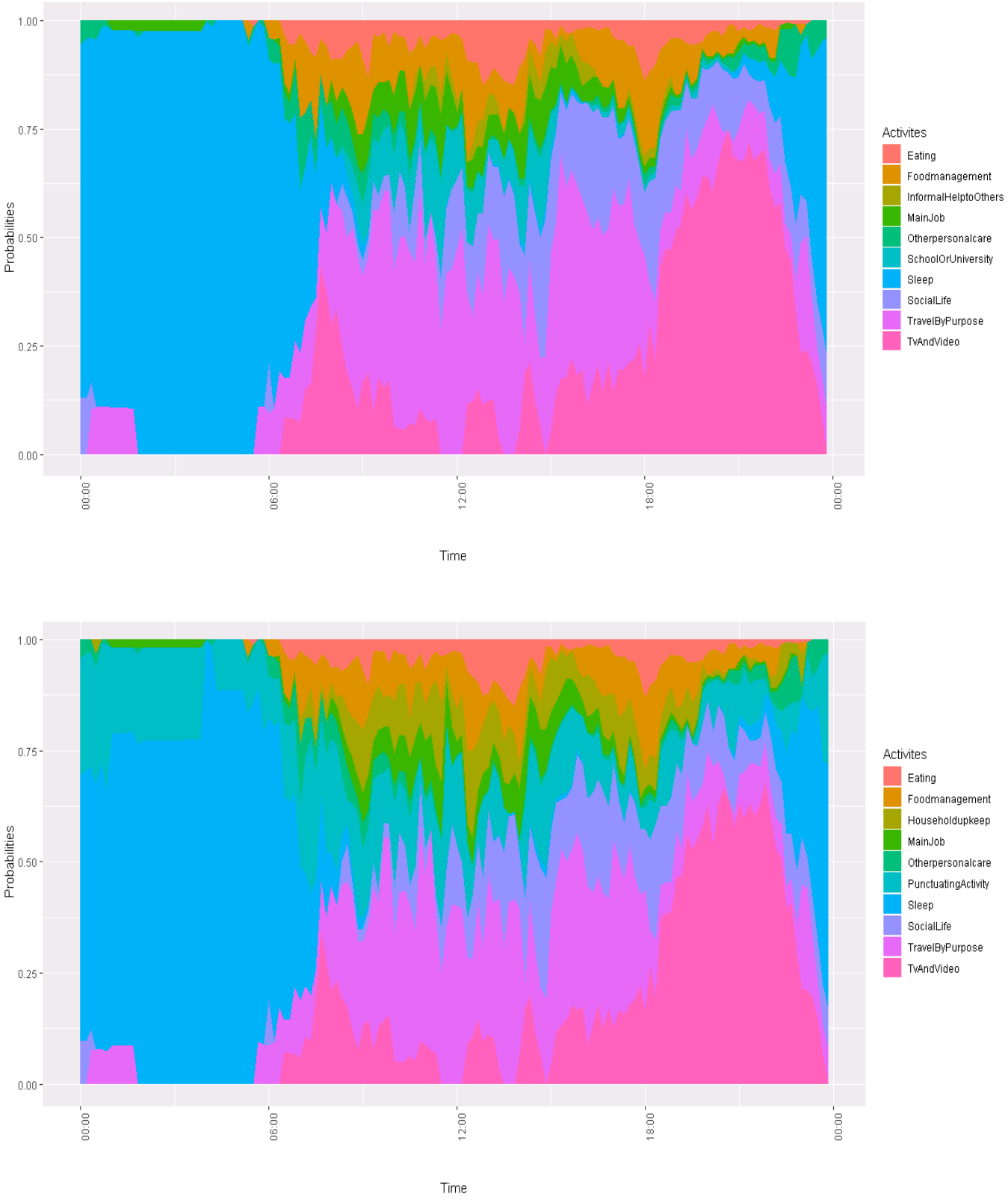

Figure 2. Comparison of the timing of activities during term dates (top) and school holidays (bottom).

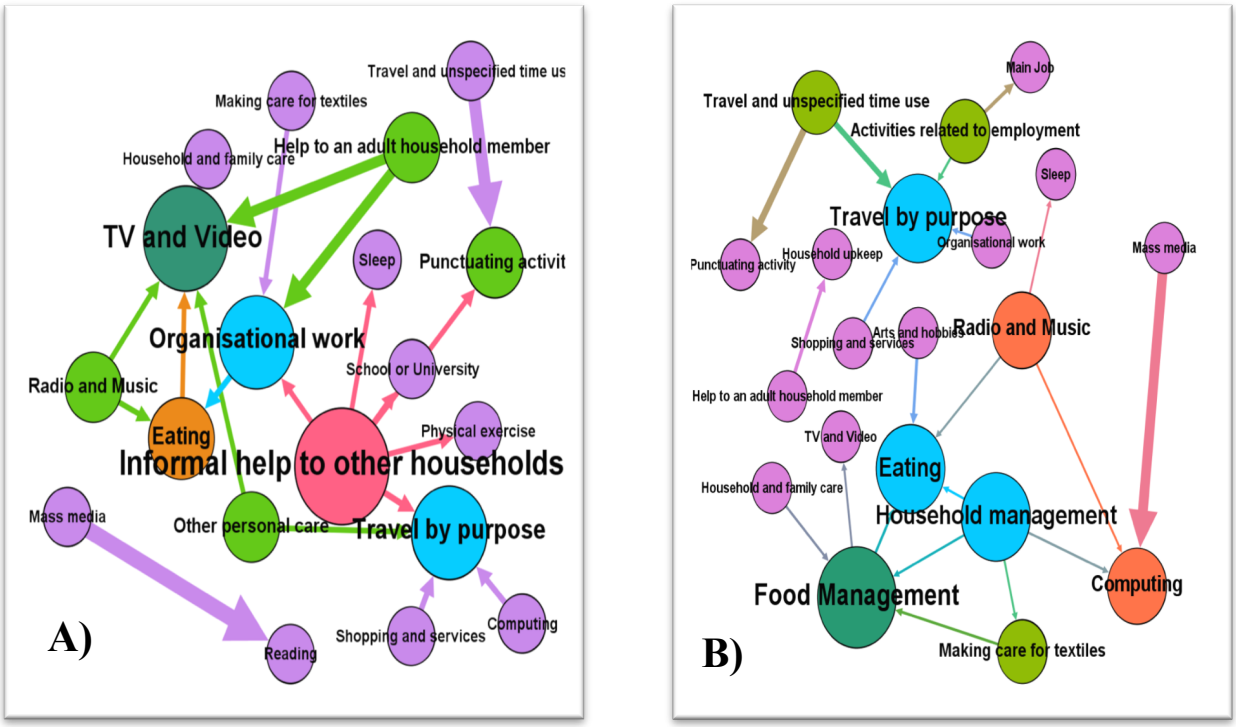

Figure 3. The 20 most frequent weekday peak time sequences of activities for two groups of consumers in employed or self-employed families with children A) during school term time and B) during school holidays.

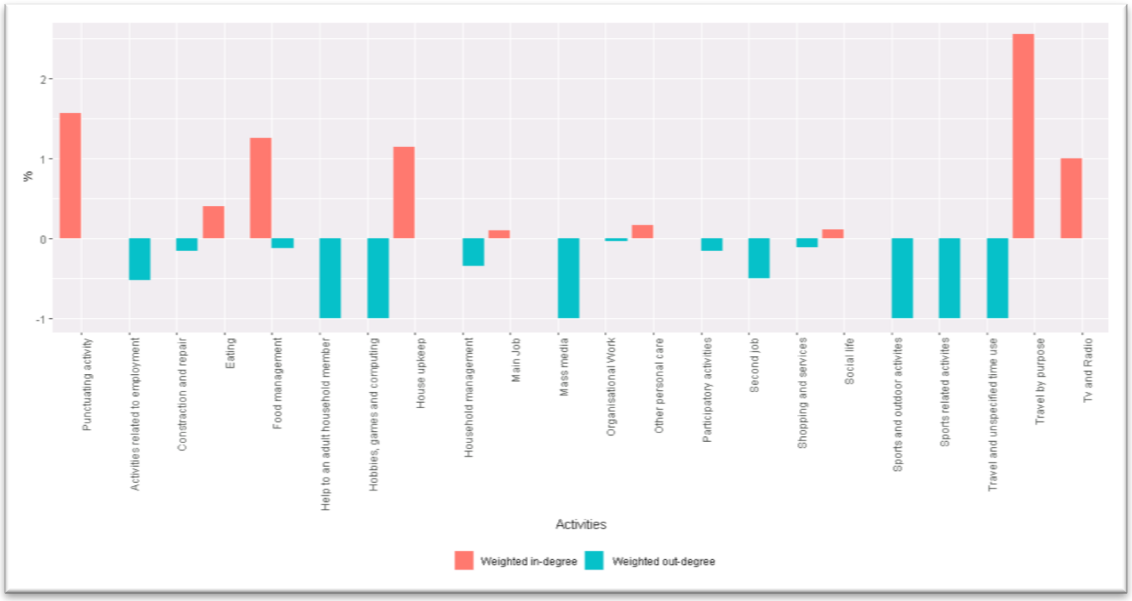

Figure 4. Degree distribution of peak time sequences of activities in employed or self-employed families with children.

The comparison of the degree [3]distribution during school terms and during holidays (Table 3) reveals travel by purpose to be the activity with the highest number of connection during holidays. Thinking about intervening to encourage change toward a more sustainable policy the network could help in identifying the number of activities that travel by purpose enable. A support non-policy measure in this case could be for example the replacement of a journey by a virtual communication or e-shopping.

Conclusion and discussions

The findings of this paper frame the problem of changing how practices interlock during working days and school holidays. The nature and the pattern of our work is changing to a more flexible and varied temporal and spatial schedules (Anderson 2016, Torriti 2017). Those who investigated the effect of working practices on commuting suggest that flexible work sched-

3. The number of nodes that point to the node in consideration is called *in-degree* of the node. The number of nodes the node in consideration point to is called *out-degree* of the node. Eg. 1->2 The in-degree of node 1 is 0 while its out-degree is 2.

Table 3. Comparison of the degree distribution during school terms and during holidays.

Id	Activities	During Term		During Holidays	
Id		Weighted Indegree	Weighted Outdegree	Weighted Outdegree	Weighted InDegree
1	Hobbies, games and computing	0	1	0	0.142857
7	Sports and outdoor activities	0	0.428571	0	0.25
8	Hobbies, games and computing	0	0.25	0	0
9	Mass media	0	0.5	0	1
10	Travel and unspecified time use	0	0.708861	0	0.73913
11	Sleep	0.107066	0	0.100078	0
12	Eating	0.259861	0	0.471344	0
13	Other personal care	0.2	0.107066	0	0.100078
21	Main Job	1.354098	0	0.291667	0
22	Second Job	0	1	0	0
23	Activities related to employment	0	0.254098	0	0.458333
41	Food Management	0.136364	0.134861	0	0.20202
42	Household upkeep	0.125	0	0	0
46	Shopping and services	0	0.101399	0.130435	0.078689
48	Childcare of own household members	0.2	0	0	0
49	Help to an adult household member	0	0.272727	0	0.103448
63	Resting-Time out	0.142857	0	0	0
71	Physical exercise	1.296703	0	0.613333	0
73	Sports related activites	0	0.384615	0	0.56
92	TV and Video	0.136364	0	0.079125	0
100	Travel by purpose	0.576291	0	0.978104	0
111	Punctuating activity	0.607595	0	0.391304	0

ules have the potential to reduce demand by shifting the time or by substituting these journeys. For example, Burkinshaw (2017) interviewed 29 work professionals with aim to investigate the potential use of home-working and time shifting amongst workers from different professions (e.g. architects, academics) that were assumed to have different access to flexible working. While his findings show no difference in flexible working arrangements between professions studied, he identifies several factors that constrain the working patterns of participants. According to this study, the main reason for the low uptake of flexible working hours is the temporal sequencing of journey to work with other activities such as household and/or school-run responsibilities or dog walking. Therefore, Burkinshaw argues that flexible working policies aiming to change patterns of commuting travel need to be understood in relation to all the other practices with which they are connected.

Using over 20 years of time use survey data Durand-Daubin et al. (2018) compared French and British cooking and eating practices focusing on where, for how long and when people engage in these practices. Their analysis revealed that the variation in place of eating depends on the type of meals as well surrounding activities that are shaping evening meals. Employment rate was identified as an influential factor for the timing of cooking and eating practices. For a future work the authors propose a sequential analysis of the connections surrounding eating and cooking to understand where, when and with who energy is shared in doing these practices.

In the sufficiency literature Sorrell et al. (2018) explored the relationship between working time and energy use/emissions. They argue even though most of studies suggest reduced working hours may be associated with reduced reductions in energy use and emissions but may not be proportional to the reduction in income. According to Sorrell et al. (2018) if individuals would reduce their working hours would have more time for leisure and they would be less concerned about saving time and more concerned about saving money and indirectly saving energy. They exemplify this idea with changes in pattern expenditure such as cooking at home instead of buying ready meals or use of public transport instead of taxi. Those who investigated the potential for non-linear relationship between working time an environmental impact contradict the above example suggesting that beyond a certain income, leisure time is used for fuelling energy intensive activities such as travelling with airplane. Therefore 'meanings' are important and framing energy as a service could help us look beyond the meter and to identify factors that influence the level of energy needed to deliver the desired service (Darby et al. 2018).

From 2013 all state schools in England can set their own holidays, over different weeks in different regions of the country. In countries like Germany and Netherlands this measure was applied to de-synchronise congestion time (Merz et al. 2005). Little work was conducted to quantify the savings from this type of intervention. Our interest is in exploring the changes that school holidays may provoke in coordination and timing of everyday energy consumption practices. In England the longest school holiday period is during the summer, when energy demands are lower. During the Christmas break the energy intensive heating, lighting costs are shifted from schools to domestic homes. Therefore if schools would extend or change the duration holidays (longer winter breaks) they could reduce energy intensive heating or lighting. On the other hand this intervention may increase the public spending. This is something that needs to be explored, and in the following we suggest ways to explore the timing and sequencing of children's practices before and during school holidays.

With regards to the synchronization of working and school holiday's practices, our work provided an interesting view of the location and orientation of food preparation activities with

regards to employment, childcare or social activities. As suggested by Durand-Daubin et al. (2018) substitution or changing the timing of domestic with workplace eating could be a powerful way to de-synchronize eating practices. On the other hand, intervening in cultural food practices requires understanding of work practices and the timing of the eating within them (Spurling et al. 2013). Another intrevention relates to food provisioning. Buying online food or ordering from grocery shops could change the sequencing of eating practices. It would be interesting to investigate what kind of new eating forms emerges as we change the sequencing of eating practices (McMekkin et al 2012, Røpke 2009).

Interventions like Time of Use tariffs will succeed in shifting the timing of electricity demand only if certain practices can be de-locked from others. Family-related activities during peak times hanging together change depending on working hours and school times. Any effective shifting of family-related activities will need to look beyond the meter (such as de-synchronized effects of school holidays), potentially collecting information regarding both energy and non-energy data in order to understand the connection, coordination and organization between activities which constitute electricity demand. From a research perspective, this can be informed through assessing the potential of non-policy measures (e.g. desynchronization of school holidays and change in work schedules) using methodologies like the one presented in this paper in order to assess reduce and manage peak loads in domestic energy demand.

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